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APPLICATION FOR UNITED STATES PATENT

FOR

ENCODING ADDRESSES IN A COMMUNICATION SYSTEM

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ENCODING ADDRESSES IN A COMMUNICATION SYSTEM

PRIORITY

The present patent application claims priority from the commonly-owned United States Provisional Patent Application No. 60/121,661 entitled CORRELATING DATA STREAMS OF DIFFERENT PROTOCOLS, which was filed on February 25, 1999 in the names of Richard Crump, Janet Doong, Okoziem Allen, and Debra Guttormsen, and is hereby incorporated herein by reference in its entirety.

CROSS-REFERENCE TO RELATED APPLICATIONS

The present patent application may be related to the following commonly-owned United States patent applications, which are hereby incorporated herein by reference in their entireties:

U.S. Patent Application No. (2204/169) entitled CORRELATING DATA STREAMS OF DIFFERENT PROTOCOLS, which was filed in the names of Richard Crump and Janet Doong on even date herewith;

U.S. Patent Application No. (2204/A12) entitled APPARATUS AND METHOD FOR BINDING A CONNECTION-ORIENTED CLIENT TO A COMMUNICATION CHANNEL, which was filed in the name of Richard Crump on even date herewith; and

U.S. Patent Application No. (2204/A13) entitled MANAGING ADDRESSES IN A COMMUNICATION SYSTEM, which was filed in the names of Richard Crump and Debra Guttormsen on even date herewith.

FIELD OF THE INVENTION

The present invention relates generally to communication systems, and more particularly to encoding addresses and using encoded addresses in a communication system.

BACKGROUND OF THE INVENTION

In today's computer age, computers and computer peripherals are often internetworked over a communication network. The various devices in the communication network, including the computers, computer peripherals, and various other networking devices, are typically assigned addresses. These addresses are used for communications between the various devices.

In order to operate in the communication network, the various network devices need to obtain and maintain certain types of addressing information. Although some addressing information may be obtained from the other network devices using various communication protocols, and other addressing information may be "learned" through normal operation of the network device, it is common for some addressing information to be configured manually. In any case, it is common for certain addressing information to be stored within each network device.

In a large communication network having many network devices, the amount of addressing information that must be obtained and maintained by the various network devices is often substantial. The large amount of addressing information makes manual configuration of addressing information tedious and error-prone. The large amount of addressing information may require large amounts of memory for storage, and may also have performance implications such as increasing address search times in various address translation and routing tables.

SUMMARY OF THE INVENTION

In accordance with one aspect of the invention, one or more addresses are encoded into a single regular expression. The regular expression may be used for configuring and/or storing addressing information in a network device.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects and advantages of the invention will be appreciated more fully from the following further description thereof with reference to the accompanying drawings wherein:

FIG. 1 is a block diagram showing an exemplary communication network having multiple X.25 end station devices connecting to one DLSw host device through a router as is known in the art;

FIG. 2 is a block diagram showing an exemplary communication network having multiple X.25 end station devices connecting to one DLSw host device through an enhanced router in accordance with an embodiment of the present invention;

FIG. 3 is a block diagram showing an exemplary communication network having multiple DLSw end station devices connecting to one X.25 host device through a router as is known in the art;

FIG. 4 is a block diagram showing an exemplary communication network having multiple DLSw end station devices connecting to one X.25 host device through an enhanced router in accordance with an embodiment of the present invention;

FIG. 5 is a block diagram showing relevant logic blocks of an exemplary network device in accordance with an embodiment of the present invention;

FIG. 6 is a table describing various wildcard characters that can be used in a regular expression in accordance with an embodiment of the present invention;

FIG. 7 is a table describing various concatenation characters that can be used in a regular expression in accordance with an embodiment of the present invention;

FIG. 8 shows an exemplary address configuration table for mapping multiple X.25 end station devices to one DLSw host device as is known in the art;

FIG. 9 shows an exemplary address configuration table for mapping multiple X.25 end station devices to one DLSw host device using a single address configuration table entry in accordance with an embodiment of the present invention;

FIG. 10 shows an exemplary dynamic routing table for mapping an X.25 end station device to a DLSw host device in accordance with an embodiment of the present invention;

FIG. 11 shows an exemplary address configuration table for mapping multiple DLSw end station devices to one X.25 host device as is known in the art;

FIG. 12 shows an exemplary address configuration table for mapping multiple DLSw end station devices to one X.25 host device using a single address configuration table entry in accordance with an embodiment of the present invention in which the X.25 logical channel number is dynamically allocated from a virtual pool of unused X.25 logical channel numbers;

FIG. 13 shows an exemplary dynamic routing table for mapping a DLSw end station device to an X.25 host device using a dynamically allocated X.25 logical channel number in accordance with an embodiment of the present invention;

FIG. 14 shows an exemplary address configuration table for mapping multiple DLSw end station devices to one X.25 host device using a single address configuration table entry in accordance with an embodiment of the present invention in which the Partner X.121 Address is dynamically allocated from an X.121 address pool;

FIG. 15 shows an exemplary dynamic routing table for mapping a DLSw end station device to an X.25 host device using a dynamically allocated Partner X.121 Address in accordance with an embodiment of the present invention; and

FIG. 16 is a table describing various operators that can be used in a regular expression.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

In an embodiment of the present invention, addressing information is encoded using regular expressions. A regular expression may be used to represent a single address

or a group of contiguous or non-contiguous addresses. A regular expression may be used for manually configuring addressing information and/or for storing addressing information. Using a regular expression to manually configure addressing information enables a network administrator to represent a group of addresses using a single regular expression, thereby simplifying the task of entering the addressing information. Storing addressing information as a regular expression enables a group of addresses to be consolidated, thereby reducing the amount of memory needed to store the addressing information.

A regular expression is a character string that is used to represent one or more addresses. A regular expression syntax defines various "wildcard" characters or character groups, concatenation characters or character groups, and operation characters that can be used in a regular expression, and also defines the rules for combining actual characters or character groups, "wildcard" characters or character groups, concatenation characters or character groups, and operation characters into a regular expression that represents one or more addresses.

Regular expressions have been used in other contexts to simplify such tasks as finding, listing, and printing. For example, under certain operating systems, an asterisk (*) may be used as a "wildcard" to match any text string. Therefore, one might enter the command "ls *.txt" to list all files having the "txt" suffix, or enter the command "print *.doc" to print all files having the "doc" suffix, or enter the command 'find "regular expression" *.*' to find all files that contain the text string "regular expression."

An embodiment of the present invention utilizes regular expressions for configuring and storing addressing information. Thus, the regular expression itself is stored in place of one or more actual addresses, for example, in an address table or management information base.

An exemplary regular expression syntax for configuring and storing addresses in a communication network device is disclosed in the provisional patent application number 60/121,661 entitled CORRELATING DATA STREAMS OF DIFFERENT PROTOCOLS, which was incorporated by reference above. The regular expression syntax defines various "wildcard" characters or character groups, concatenation characters or character groups,

and operation characters that can be used in a regular expression, and also defines the rules for combining actual characters or character groups, "wildcard" characters or character groups, concatenation characters or character groups, and operation characters into a regular expression that represents one or more addresses.

Except for specific wildcard characters, a character in a regular expression is used to match that character. For example, the regular expression "400000000004" matches only the address "400000000004."

As shown in FIG. 6, a period (.) is a wildcard character that is used to match any single character. For example, the regular expression "40000000000." matches the addresses "400000000000," "400000000001," "400000000002," and so on.

As shown in FIG. 6, a caret (^) is a wildcard character that, when included in the leftmost position of a regular expression, constrains the regular expression to match the leftmost portion of an address, and is therefore referred to as an "anchor."

As shown in FIG. 6, a dollar sign ($) is a wildcard character that, when included in the rightmost position of a regular expression, constrains the regular expression to match the rightmost portion of an address, and is therefore also referred to as an "anchor."

As shown in FIG. 6 and FIG. 16, a bracketed group can be used to define a group of characters for a single character position within the regular expression. A bracketed group includes an expression that is enclosed within square brackets. For purposes of various concatenation rules that are described below, a bracketed group is treated like a single-character expression.

A bracketed group that includes multiple characters matches any one of the characters at the position in the regular expression at which the bracketed group is included. For example, the bracketed group "[567]" matches a "5," a "6," or a "7" at the position in the regular expression at which the bracketed group is included, such that the regular expression "40000000000[567]" matches the addresses 400000000005, 400000000006, and 400000000007.

A bracketed group that includes an expression beginning with a caret (^) matches any character at the position in the regular expression at which the bracketed group is included EXCEPT for the characters following the caret. For example, the bracketed

group "[^567]" matches any character except a "5," a "6," or a "7" at the position in the regular expression at which the bracketed group is included.

A bracketed group that includes a minus sign (-) between two characters matches any character at the position in the regular expression at which the bracketed group is included that is in the range of consecutive characters beginning with the leftmost character and ending with the rightmost character. For example, the bracketed group "[5-7]" matches a "5," a "6," or a "7" at the position in the regular expression at which the bracketed group is included, such that the regular expression "40000000000[5-7]"matches the addresses 400000000005, 400000000006, and 400000000007.

As shown in FIG. 16, a parenthetical group can be used to correlate multiple expressions. A parenthetical group includes multiple expressions that are enclosed within parentheses. A parenthetical group matches whatever the enclosed expressions match. For purposes of various concatenation rules that are described below, a parenthetical group is treated like a single expression.

Within a parenthetical group, two expressions separated by a vertical bar (|) matches either expression. For example, the parenthetical group "(12|16)" matches either a "12" or a "16" at the position in the regular expression at which the parenthetical group is included, such that the regular expression "7777(12|16)" matches the addresses 777712 and 777716.

As shown in FIG. 7, a question mark (?) is a concatenation character that matches zero or exactly one occurrence of the expression that immediately precedes it. The preceding expression may be a single character, a wildcard character, a bracketed group, or a parenthetical group. For example, the expression "[0-9]?" matches any string having zero or exactly one digit.

As shown in FIG. 7, an asterisk (*) is a concatenation character that matches zero or more occurrences of the expression that immediately precedes it. The preceding expression may be a single character, a wildcard character, a bracketed group, or a parenthetical group. For example, the expression "[0-9]*" matches any string having zero or more digits. The regular expression ".*" (i.e., the two-character string consisting of a period followed by an asterisk) represents a universal address that matches any and all

addresses, since the period (.) matches any character and the asterisk (*) indicates zero or more occurrences of any character.

As shown in FIG. 7, a plus sign (+) is a concatenation character that matches one or more occurrences of the expression that immediately precedes it. The preceding expression may be a single character, a wildcard character, a bracketed group, or a parenthetical group. For example, the expression "[0-9]+" matches any string having one or more digits.

As shown in FIG. 7, a braced group can be used to specify a specific number or range of occurrences of the expression that immediately precedes it. A braced group is enclosed within braces (curly brackets). A braced group of the form "{m}" matches exactly "m" occurrences of the expression that immediately precedes it. A braced group of the form "{m,}" matches at least "m" occurrences of the expression that immediately precedes it. A braces group of the form "{m,n}" at least "m" but no more than "n" occurrences of the expression that immediately precedes it.

In an exemplary embodiment of the present invention, regular expressions may be used to simply the configuration of address mapping information and also to configure address pools. In a typical communication network, it is common for the various network devices in the communication network to include various address mapping tables. Address mapping tables are used in many contexts. One exemplary address mapping table maps each destination address to a corresponding route, and may be used, for example, for forwarding protocol messages. Another exemplary address mapping table maps an address from one network domain to a corresponding address in another network domain, and may be used, for example, for translating addresses in a network address translator. Yet another exemplary address mapping table maps an address from one protocol to an address of another protocol, and may be used, for example, for correlating data streams of different protocols. In certain applications, the use of a regular expression in place of multiple addresses in an address mapping table may necessitate that various related addresses be dynamically allocated from an address pool. A regular expression may be used to configure the address pool.

Various aspects of the present invention can be demonstrated by example with reference to a communication system having an X.25 network that is interconnected with a DLSw network through a router or other intermediate network device. In a first exemplary embodiment, multiple X.25 clients in the (source) X.25 network initiate connections to a single DLSw host in the (destination) DLSw network. In a second exemplary embodiment, multiple DLSw clients in the (source) DLSw network initiate connections to a single X.25 host in the (destination) X.25 network.

X.25 is a common packet switching protocol that uses a Packet Layer Protocol (PLP) to perform network routing functions and multiplexing of simultaneous logical connections over a single physical connection. Data Link Switching (DLSw) is a connection-oriented forwarding mechanism for the IBM Systems Network Architecture (SNA). Qualified Logical Link Control (QLLC) is a protocol that allows SNA data to be transported across connection-oriented X.25 networks. Considerable configuration support is required of network router software to implement QLLC for various Data Link Switching (DLSw) protocol network topologies.

Data routing in a connection-oriented protocol such as DLSw is typically based on a Media Access Control (MAC) hardware address that is uniquely associated with each node in the network. However, the X.25 network uses X.121 addresses to identify the source and destination for message streams.

When a router device is used to interconnect a device in one network, such as a connection-oriented DLSw network, with a device in another network, such as a connection-oriented X.25 network, an address configuration table must be configured in order to map each device to the other. For example, when mapping DLSw devices and X.25 devices in a prior art embodiment, the information in the address configuration table includes source and destination MAC addresses for the DLSw devices, and calling and called X.121 addresses for the X.25 devices. One table entry is made in the address table for each pair of interconnected devices. In order to establish a connection between a DLSw device and an X.25 device, a router device refers to the address configuration table entries to establish a dynamic routing mapping, for example in a dynamic routing table, that is used for the two-way exchange of data messages between the mapped devices. At

the end of a communications session, the dynamic routing table entry may be positively deleted by the router, or, may simply "age" out of the dynamic routing table.

Even in a relatively simple network topology, a significant number of address configuration table entries may need to be entered. This may be a tedious, time-consuming process of a network technician with many other pressing tasks to be performed. In addition, entering a large number of addresses by hand is likely to result in a significant number of errors.

Therefore, in an exemplary embodiment of the present invention, a single address configuration table entry maps multiple source devices in a source network to a single destination device in a destination network. The single address configuration table entry is used when any of the source devices initiates a connection to the destination device. The single address configuration table entry includes a "wildcard" for matching the source address of connection requests that are originated by any of the multiple source devices and destined for the destination device. Because the "wildcard" may match multiple source addresses, the single address configuration table entry does not represent a one-to-one mapping of a source device from the source network to a destination device in the destination network. Therefore, in order to establish a connection from a source device in the source network to a destination device in the destination network using the single address configuration table entry, certain address/channel information is dynamically allocated at the time the connection is established, and a dynamic routing table entry is installed in a dynamic routing table in order to map the source device to the destination device using the dynamically allocated address/channel information. In this way, a router or other intermediate network device is able to maintain one address configuration table entry per destination device rather than one address configuration table entry per source device, as in the prior art. Such an arrangement greatly reduces the complexity of configuring address mapping information.

Within the communication system, each client/host device is associated with an X.121 address for the X.25 network as well as a MAC address for the DLSw network. Address mapping information must be configured in order to enable connection establishment between the X.25 devices in the X.25 network and the DLSw devices in the

DLSw network. The router stores the address mapping information in the address configuration table. The router uses the address mapping information in the address configuration table for establishing connections.

In an embodiment of the present invention, the address mapping information is configured differently depending on whether connections are initiated from the X.25 network or from the DLSw network. When connections are initiated from the X.25 network, each address configuration table entry maps one or more (source) X.25 devices in the (source) X.25 network to a single (destination) DLSw device in the (destination) DLSw network. When connections are initiated from the DLSw network, each address configuration table entry maps one or more (source) DLSw devices in the (source) DLSw network to a single (destination) X.25 device in the (destination) X.25 network.

Because the designations "source" and "destination" are relative to the network from which the connections are initiated, it is convenient to introduce the terms "adjacent" and "partner" to describe addresses that are associated with an X.25 device and a DLSw device, respectively. Thus, an address configuration table entry includes, among other things, an Adjacent X.121 Address field, a Partner X.121 Address field, an Adjacent MAC Address field, a Partner MAC Address field, and a Flag field. The Flag field indicates whether the Partner MAC Address field contains an actual MAC address or a regular expression ("wildcard").

When connections are initiated from the X.25 network, the Adjacent X.121 Address field is configured as a "wildcard" using a regular expression in order to match one or more (source) X.25 device addresses. An exemplary embodiment of the present invention utilizes the regular expression ".*" (i.e., the two-character string consisting of a period followed by an asterisk) as the "wildcard" in order to match any address. The Adjacent MAC Address field is left blank (nil). When a connection is established, the Adjacent MAC Address for the connection is dynamically allocated from a predetermined MAC address pool.

When connections are initiated from the DLSw network, the Partner MAC Address field is configured as a "wildcard" using a regular expression in order to match one or more (source) DLSw device addresses. An exemplary embodiment of the present

invention utilizes the regular expression ".*" (i.e., the two-character string consisting of a period followed by an asterisk) as the "wildcard" in order to match any address. The Partner X.121 Address field may be configured to be the X.121 address associated with an implied source device (such as the router), in which case an X.25 logical channel number (LCN) is dynamically allocated for the connection when the connection is established, or the Partner X.121 Address field may be left blank (nil), in which case the Partner X.121 Address is dynamically allocated for the connection when the connection is established. Either the X.25 LCN or the Partner X.121 Address is dynamically allocated because each X.25 session is required to have a unique LCN/X.121 pair in order to differentiate the various X.25 sessions. In the former case, the same Partner X.121 Address (i.e., the X.121 address associated with the implied source device) is used for each X.25 session, and therefore a different X.25 LCN is used for each X.25 session in order to distinguish the various X.25 sessions. In the latter case, the same X.25 LCN is used for each X.25 session, and therefore a different Partner X.121 Address is used for each X.25 session in order to distinguish the various X.25 sessions.

Once a connection is established, the router installs a dynamic routing table entry in the dynamic routing table. The dynamic routing table entry includes, among other things, an Adjacent X.121 Address field, a Partner X.121 Address field, an actual or implied X.25 LCN field, an Adjacent MAC Address field, and a Partner MAC Address field. The dynamic routing table entry includes addressing information for mapping a single X.25 device to a single DLSw device including any dynamically allocated address/channel information. The dynamic routing table entry does not include any "wildcard" or "nil" values. The router uses the dynamic routing table entry for forwarding packets between the X.25 device and the DLSw device, irrespective of which side initiated the connection.

Specifically, when a connection is initiated by an X.25 device, the X.25 device specifies a calling X.121 address corresponding to the source X.25 device and a called X.121 address corresponding to the destination DLSw device. The router searches the address configuration table for an address configuration table entry having the Adjacent X.121 Address field matching the calling X.121 address (via a "wildcard") and the Partner

X.121 Address field equal to the called X.121 address. Upon finding such an address configuration table entry, the router obtains the Partner MAC Address from the address configuration table entry, and allocates an Adjacent MAC Address from the predetermined MAC address pool. The router then attempts to establish a connection to the destination DLSw device using the allocated Adjacent MAC Address as the source MAC address and the Partner MAC Address as the destination MAC address. Assuming the router is able to establish the connection to the destination DLSw device, the router installs a dynamic routing table entry in the dynamic routing table. Within the dynamic routing table entry, the Adjacent X.121 Address field is equal to the calling X.121 address specified by the source X.25 device, the Partner X.121 Address field is equal to the called X.121 address specified by the source X.25 device, the X.25 LCN field is equal to the X.25 LCN associated with the connection (which, in a preferred embodiment, defaults to 1), the Adjacent MAC Address field is equal to the MAC address that the router allocated from the MAC address pool, and the Partner MAC Address field is equal to the Partner MAC Address field from the address configuration table entry.

On the other hand, when a connection is initiated by a DLSw device, the DLSw device specifies a source MAC address corresponding to the source DLSw device and a destination MAC address corresponding to the destination X.25 device. The router searches the address configuration table for an address configuration table entry having the Partner MAC Address field matching the source MAC address (via a "wildcard) and the Adjacent MAC Address field equal to the destination MAC address. Upon finding such an address configuration table entry, the router obtains the Adjacent X.121 Address from the address configuration table entry, and determines from the Partner X.121 Address field whether to dynamically allocate an X.25 LCN for the connection or to dynamically allocate a Partner X.121 Address for the connection. If the Partner X.121 Address field includes a usable X.121 address, then the router dynamically allocates an X.25 LCN from a "virtual pool" of unused X.25 LCNs. If the Partner X.121 Address field is "nil," then the router dynamically allocates a Partner X.121 Address from a predetermined pool of X.121 addresses. In either case, the router then attempts to establish a connection to the destination X.25 device using the Partner X.121 Address as the calling X.121 address and

the Adjacent X.121 Address as the called X.121 address. Assuming the router is able to establish the connection to the destination X.25 device, the router installs a dynamic routing table entry in the dynamic routing table. If the router dynamically allocated the X.25 LCN, then the Adjacent X.121 Address field is equal to the Adjacent X.121 Address field from the address configuration table entry, the Partner X.121 Address field is equal to the Partner X.121 Address field from the address configuration table entry, the X.25 LCN field is equal to the allocated X.25 LCN, the Adjacent MAC Address field is equal to the destination MAC address specified by the source DLSw device, and the Partner MAC Address field is equal to the source MAC address specified by the source DLSw device. If the router dynamically allocated the Partner X.121 Address, then the Adjacent X.121 Address field is equal to the Adjacent X.121 Address field from the address configuration table entry, the Partner X.121 Address field is equal to the allocated Partner X.121 Address, the X.25 LCN field is equal to a predetermined X.25 LCN, the Adjacent MAC Address field is equal to the destination MAC address specified by the source DLSw device, and the Partner MAC Address field is equal to the source MAC address specified by the source DLSw device.

INITIATING A CONNECTION FROM THE X.25 NETWORK

FIG. 1 shows an exemplary prior art communication network **100** having multiple X.25 end station devices initiating connections to one DLSw host device. More specifically, a DLSw network **10** is connected to downstream QLLC compatible X.25 devices **121**, **122**, and **123** via an X.25 network **14** that includes the router device **13**. The DLSw network **10** is also connected via a token ring network **15** to upstream host LLC device SNA mainframe **16**. The personal computer **121** is a QLLC X.25 device having an X.121 address of 77771 and a MAC address of 400000000001. The IBM 3174 **122** is a QLLC X.25 device having an X.121 address of 77773 and a MAC address of 400000000003. The IBM AS/400 **123** is a QLLC X.25 device having an X.121 address of 77772 and a MAC address of 400000000002. The host SNA mainframe **16** is an LLC

protocol DLSw device having an X.121 address of 4444 and a MAC address of 400000000004. The router **13** has an X.121 address of 7777.

In order for the X.25 devices (**121**, **122**, **123**) to connect to the host SNA mainframe **16**, address mapping information must be configured to map each X.25 device (**121**, **122**, **123**) to the host SNA mainframe **16**. A complete set of address mapping information is configured for each pair of interconnected devices. This address mapping information includes the X.121 addresses and MAC addresses for each pair of interconnected devices. Thus, in a topology where many X.25 client devices need access to a single DLSw host device, address mapping information is configured for each X.25 client device.

FIG. 8 shows an exemplary prior art address configuration table **800** for use in the router device **13** in the network illustrated in FIG. 1. The address configuration table **800** includes three address configuration table entries (**812**, **814**, **816**), one for each X.25 device (**121**, **122**, **123**). Each address configuration table entry (**812**, **814**, **816**) includes a Map Name field **802**, an Adjacent X.121 Address field **804**, a Partner X.121 Address field **804**, an Adjacent MAC Address field **808**, and a Partner MAC Address field **810**. The Map Name field **802** is used to name a specific address configuration table entry. The Adjacent X.121 Address field **804** indicates the X.121 address of the X.25 client device. The Partner X.121 Address field **804** indicates the X.121 address of the DLSw host device. The Adjacent MAC Address field **808** indicates the MAC address of the X.25 client device. The Partner MAC Address field **810** indicates the MAC address of the DLSw host device.

The address configuration table **800** shows three exemplary address configuration table entries, specifically address configuration table entries **812**, **814**, and **816**. Address configuration table entry **812**, which has a Map Name AS400_map, corresponds to the connection from the IBM AS/400 **123** to the SNA mainframe **16**, and thus includes Adjacent X.121 Address 77772, Partner X.121 Address 4444, Adjacent MAC Address 400000000002, and Partner MAC Address 400000000004. Address configuration table entry **814**, which has a Map Name 3174_map, corresponds to the connection from the IBM 3174 **122** to the SNA mainframe **16**, and thus includes Adjacent X.121 Address 77773,

Partner X.121 Address 4444, Adjacent MAC Address 400000000003, and Partner MAC Address 400000000004. Address configuration table entry **816**, which has a Map Name PC_map, corresponds to the connection from the personal computer workstation PC **122** to the SNA mainframe **16**, and thus includes Adjacent X.121 Address 77771, Partner X.121 Address 4444, Adjacent MAC Address 400000000001, and Partner MAC Address 400000000004.

When, for example, the AS/400 **123** initiates a connection to the SNA mainframe **16**, the AS/400 **123** generates a connection request including, among other things, a calling X.121 address equal to the X.121 address of the AS/400 **123** (77772) and a called X.121 address equal to the X.121 address of the SNA mainframe **16** (4444). When the router device **13** receives this connection request from the AS/400 **123**, the router device **13** searches the address configuration table **800** for an address configuration table entry having an Adjacent X.121 Address **804** matching the calling X.121 address of 77772 and a Partner X.121 Address **806** matching the called X.121 address of 4444. In this example, the router device **13** finds the address configuration table entry **812**.

Upon finding the address configuration table entry **812**, router device **13** obtains the corresponding Adjacent MAC Address **808** of 400000000002 and the corresponding Partner MAC Address **810** of 400000000004 from the address configuration table entry **812**, and attempts to connect to the SNA mainframe **16** using a source MAC address equal to the Adjacent MAC Address **808** of 400000000002 and a destination MAC address equal to the Partner MAC Address **810** of 400000000004.

The communication network **200** shown in FIG. 2 is similar to the communication network **100** shown in FIG. 1, but uses an enhanced router device **23** having an enhanced address configuration table for mapping multiple X.25 devices to a single DLSw device using a single address configuration table entry. More specifically, a DLSw network **20** is connected to downstream QLLC compatible X.25 devices **221**, **222**, and **223** via an X.25 network **24** that includes the enhanced router device **23**. The DLSw network **20** is also connected via a token ring network **25** to upstream host LLC device SNA mainframe **26**. In the network depicted in FIG. 2, the personal computer **221** is a QLLC X.25 device having an X.121 address of 77771. The IBM 3174 **222** is a QLLC X.25 device having an

X.121 address of 77773. The IBM AS/400 **223** is a QLLC X.25 device having an X.121 address of 77772. The X.25 devices (**221**, **222**, **223**) may be assigned MAC addresses, as in the prior art embodiment shown in FIG. 1, although the X.25 devices (**221**, **222**, **223**) need not be assigned such MAC addresses, since the enhanced router **23** dynamically assigns MAC addresses for the X.25 devices (**221**, **222**, **223**) from a MAC address pool. The host SNA mainframe **26** is an LLC protocol DLSw device having an X.121 address of 4444 and a MAC address of 400000000004. The enhanced router **23** has an X.121 address of 7777.

In order for the X.25 devices (**221**, **222**, **223**) to connect to the host SNA mainframe **26**, a single address configuration table entry that maps all X.25 devices (**221**, **222**, **223**) to the host SNA mainframe **26** is installed in the address configuration table. The single address configuration table entry includes a "wildcard" for matching all X.25 device addresses, and includes the X.121 address and the MAC address associated with the host SNA mainframe **26**. Thus, address mapping information is configured for the single DLSw host device rather than for each X.25 client device.

FIG. 9 shows an exemplary address configuration table **900** for use in the enhanced router device **23** in the network illustrated in FIG. 2. The address configuration table **900** includes a single address configuration table entry **912** for mapping the X.25 devices (**221**, **222**, **223**) to the host SNA mainframe **26**. The address configuration table entry **912** includes a Map Name field **902**, an Adjacent X.121 Address field **904**, a Partner X.121 Address field **906**, an Adjacent MAC Address field **908**, a Partner MAC Address field **910**, and a Flag field **911**. The Map Name field **902** includes an address configuration table entry name, which, in this example, is "Host1_map." The Adjacent X.121 Address field **904** includes a "wildcard" matching all X.25 device addresses. The Partner X.121 Address field **906** includes the X.121 address 4444 that is associated with the host SNA mainframe **26**. The Adjacent MAC Address field **908** is "nil," which indicates that the source MAC address is to be allocated from the MAC address pool. The Partner MAC Address field **910** includes the MAC address 400000000004 that is associated with the host SNA mainframe **26**. The Flag field **911** is zero, which indicates that there is no "wildcard" in the Partner MAC Address field **910**.

When, for example, the AS/400 **223** initiates a connection to the SNA mainframe **26**, the AS/400 **223** generates a connection request including, among other things, a calling X.121 address equal to the X.121 address of the AS/400 **223** (77772) and a called X.121 address equal to the X.121 address of the SNA mainframe **26** (4444). When the enhanced router device **23** receives this connection request from the AS/400 **223**, the enhanced router device **23** searches the address configuration table **900** for an address configuration table entry having an Adjacent X.121 Address **904** matching the calling X.121 address of 77772 and a Partner X.121 Address **906** equal to the called X.121 address of 4444. In this example, the enhanced router device **23** finds the address configuration table entry **912**.

Upon finding the address configuration table entry **912**, enhanced router device **23** obtains the corresponding Partner MAC Address **910** of 400000000004 from the address configuration table entry **912**, but is unable to obtain an Adjacent MAC Address from the address configuration table entry **912** since the Adjacent MAC Address field **908** is "nil." Therefore, the enhanced router device **23** allocates the Adjacent MAC Address from a MAC address pool. For example, assume that the enhanced router device **23** allocates the MAC address 400000000005 from a MAC address pool containing the MAC addresses 400000000005, 400000000006, and 400000000007. The enhanced router device **23** then attempts to connect to the host SNA mainframe **26** using a source MAC address equal to the allocated Adjacent MAC Address of 400000000005 and a destination MAC address equal to the Partner MAC Address **910** of 400000000004. If the enhanced router device **23** is able to establish the connection to the host SNA mainframe **26**, then the enhanced router device **23** installs a dynamic routing table entry in the dynamic routing table mapping the AS/400 **223** to the host SNA mainframe **26**.

FIG. 10 shows an exemplary dynamic routing table **1000** including a dynamic routing table entry **1012** mapping the AS/400 **223** to the host SNA mainframe **26**. The dynamic routing table entry **1012** includes an Adjacent X.121 Address field **1004** equal to the calling X.121 address of 77772, a Partner X.121 Address field **1006** equal to the called X.121 address of 4444, an X.25 LCN field **1007** equal to a predetermined X.25 LCN of 1, an Adjacent MAC Address field **1008** equal to the allocated Adjacent MAC Address of 400000000005, and a Partner MAC Address field **1010** equal to the Partner MAC Address

of 400000000004. The enhanced router device **23** uses the dynamic routing table entry **1012** to translate between X.121 addresses and MAC address for communication between the AS/400 **223** and the host SNA mainframe **26**. For example, when the enhanced router device **23** receives an X.25 packet from the AS/400 **223** including a calling X.121 address of 77772 and a called X.121 address of 4444, the enhanced router device **23** uses the dynamic routing table entry **1012** to translate the calling X.121 address of 77772 into a source MAC address of 400000000005 and to translate the called X.121 address of 4444 into a destination MAC address of 400000000004. Similarly, when the enhanced router device **23** receives a DLSw packet from the host SNA mainframe **26** including a source MAC address of 400000000004 and a destination MAC address of 400000000005, the enhanced router device **23** uses the dynamic routing table entry **1012** to translate the source MAC address of 400000000004 into a calling X.121 address of 4444 and to translate the destination MAC address of 400000000005 into a called X.121 address of 77772.

INITIATING A CONNECTION FROM THE DLSw NETWORK

FIG. 3 shows an exemplary prior art communication network **300** having multiple DLSw end station devices initiating connections to one X.25 host device. More specifically, a DLSw network **30** is connected to an upstream QLLC X.25 device host **32** via an X.25 network **34** that includes the router device **33**. The DLSw network **30** is also connected via a token ring network **35** to downstream LLC-attached SNA end stations **361**, **362**, and **363**. The personal computer **361** is an LLC-attached DLSw device having a MAC address of 400000000001 and an X.121 address of 77771. The IBM 3174 **362** is an LLC-attached DLSw device having a MAC address of 400000000003 and an X.121 address of 77773. The IBM AS/400 **363** is an LLC-attached DLSw device having a MAC address of 400000000002 and an X.121 address of 77772. The host SNA mainframe **32** is a QLLC X.25 device having a MAC address of 400000000004 and an X.121 address of 3745. The router **33** has an X.121 address of 7777.

In order for the DLSw devices (**361**, **362**, **363**) to connect to the host SNA mainframe **32**, address mapping information must be configured to map each DLSw device (**361**, **362**, **363**) to the host SNA mainframe **32**. A complete set of address mapping information is configured for each pair of interconnected devices. This address mapping information includes the X.121 addresses and MAC addresses for each pair of interconnected devices. Thus, in a topology where many DLSw devices need access to a single X.25 host device, address mapping information is configured for each DLSw client device.

FIG. 11 shows an exemplary prior art QLLC address configuration mapping table **1100** for use in the router device **33** in the network illustrated in FIG. 3. The address configuration table **1100** includes three address configuration table entries (**1112**, **1114**, **1116**), one for each DLSw device (**361**, **362**, **363**). Each address configuration table entry (**1112**, **1114**, **1116**) includes a Map Name field **1102**, an Adjacent X.121 Address field **1104**, a Partner X.121 Address field **1106**, an Adjacent MAC Address field **1108**, and a Partner MAC Address field **1110**. The Map Name field **1102** is used to name a specific address configuration table entry. The Adjacent X.121 Address **1104** indicates the X.121 address of the X.25 host device. The Partner X.121 Address **1106** indicates the X.121 address of the DLSw client device. The Adjacent MAC Address **1108** indicates the MAC address of the X.25 host device. The Partner MAC Address **1110** indicates the MAC address of the DLSw client device.

The address configuration table **1100** shows three exemplary address configuration table entries, specifically address configuration table entries **1112**, **1114**, and **1116**. Address configuration table entry **1112**, which has a Map Name AS400_map, corresponds to the connection from the IBM AS/400 **363** to the SNA mainframe **32**, and thus includes Adjacent X.121 Address 3745, Partner X.121 Address 77772, Adjacent MAC Address 400000000004, and Partner MAC Address 400000000002. Address configuration table entry **1114**, which has a Map Name 3174_map, corresponds to the connection from the IBM 3174 **362** to the SNA mainframe **32**, and thus includes Adjacent X.121 Address 3745, Partner X.121 Address 77773, Adjacent MAC Address 400000000004, and Partner MAC Address 400000000003. Address configuration table entry **1116**, which has a Map

Name PC_map, corresponds to the connection from the personal computer workstation PC **361** to the SNA mainframe **32**, and thus includes Adjacent X.121 Address 3745, Partner X.121 Address 77771, Adjacent MAC Address 400000000004, and Partner MAC Address 400000000001.

When, for example, the AS/400 **363** initiates a connection to the SNA mainframe **32**, the AS/400 **363** generates a connection request including, among other things, a source MAC address equal to the MAC address of the AS/400 **363** (400000000002) and a destination MAC address equal to the MAC address of the SNA mainframe **32** (400000000004). When the router device **33** receives this connection request from the AS/400 **363**, the router device **33** searches the address configuration table **1100** for an address configuration table entry having a Partner MAC Address **1110** matching the source MAC address of 400000000002 and an Adjacent MAC Address **1108** matching the destination MAC address of 400000000004. In this example, the router device **33** finds the address configuration table entry **1112**.

Upon finding the table entry **1112**, router device **33** obtains the corresponding Partner X.121 Address **1106** of 77772 and the corresponding Adjacent X.121 Address **1104** of 3745 from the address configuration table entry **1112**, and attempts to connect to the SNA mainframe **32** using a calling X.121 address equal to the Partner X.121 Address **1106** of 77772 and a called X.121 address equal to the Adjacent X.121 Address **1104** of 3745.

The communication network **400** shown in FIG. 4 is similar to the communication network **300** shown in FIG. 3, but uses an enhanced router device **43** having an enhanced address configuration table for mapping multiple DLSw devices to a single X.25 device using a single address configuration table entry. More specifically, a DLSw network **40** is connected to an upstream QLLC X.25 device host **42** via an X.25 network **44** that includes the enhanced router device **43**. The DLSw network **40** is also connected via a token ring network **45** to downstream LLC-attached SNA end stations **461**, **462**, and **463**. The personal computer **461** is an LLC-attached DLSw device having a MAC address of 400000000001. The IBM 3174 **462** is an LLC-attached DLSw device having a MAC address of 400000000003. The IBM AS/400 **463** is an LLC-attached DLSw device having

a MAC address of 400000000002. The DLSw devices (**461**, **462**, **463**) may be assigned X.121 addresses, as in the prior art embodiment shown in FIG. 3, although the DLSw devices (**461**, **462**, **463**) need not be assigned such X.121 addresses, since the enhanced router **43** either dynamically assigns X.121 addresses for the DLSw devices (**461**, **462**, **463**) from an X.121 address pool or uses the X.121 address of the enhanced router **43**. The host SNA mainframe **42** is a QLLC X.25 device having a MAC address of 400000000004 and an X.121 address of 3745. The enhanced router **43** has an X.121 address of 7777.

In order for the DLSw devices (**461**, **462**, **463**) to connect to the host SNA mainframe **42**, a single address configuration table entry that maps all DLSw devices (**461**, **462**, **463**) to the host SNA mainframe **42** is installed in the address configuration table. The single address configuration table entry includes a "wildcard" for matching all DLSw device addresses, and includes the X.121 address and the MAC address associated with the host SNA mainframe **42**. Thus, address mapping information is configured for the single X.25 host device rather than for each DLSw client device.

In one embodiment of the invention, the enhanced router device **43** uses the same Partner X.121 Address for all connections and dynamically allocates a different X.25 LCN for each connection. In another embodiment of the invention, the enhanced router device **43** uses the same X.25 LCN for all connections and dynamically allocates a different Partner X.121 Address for each connection. An example of each scheme is described below.

DYNAMICALLY ALLOCATE X.25 LCN

FIG. 12 shows an exemplary address configuration table **1200** for use in the enhanced router device **43** when the enhanced router device **43** dynamically allocates the X.25 LCNs. The address configuration table **1200** includes a single address configuration table entry **1212** for mapping the DLSw devices (**461**, **462**, **463**) to the host SNA mainframe **42**. The address configuration table entry **1212** includes a Map Name field **1202**, an Adjacent X.121 Address field **1204**, a Partner X.121 Address field **1206**, an

Adjacent MAC Address field **1208**, a Partner MAC Address field **1210**, and a Flag field **1211**. The Map Name field **1202** includes an address configuration table entry name, which, in this example, is "NPSI_host." The Adjacent X.121 Address field **1204** includes the X.121 address 3745 that is associated with the host SNA mainframe **42**. The Partner X.121 Address field **1206** includes the X.121 address 7777 that is associated with the enhanced router **43**. The Adjacent MAC Address field **1208** includes the MAC address 400000000004 that is associated with the host SNA mainframe **42**. The Partner MAC Address field **1210** includes a "wildcard" matching all DLSw device addresses. The Flag field **1211** is equal to one, which indicates that there is a "wildcard" in the Partner MAC Address field **1210**.

When, for example, the AS/400 **463** initiates a connection to the SNA mainframe **42**, the AS/400 **463** generates a connection request including, among other things, a source MAC address equal to the MAC address of the AS/400 **463** (400000000002) and a destination MAC address equal to the MAC address of the SNA mainframe **42** (400000000004). When the enhanced router device **43** receives this connection request from the AS/400 **463**, the enhanced router device **43** searches the address configuration table **1200** for an address configuration table entry having a Partner MAC Address **1210** matching the source MAC address of 400000000002 and an Adjacent MAC Address **1208** matching the destination MAC address of 400000000004. In this example, the enhanced router device **43** finds the address configuration table entry **1212**.

Upon finding the table entry **1212**, enhanced router device **43** obtains the corresponding Partner X.121 Address **1206** of 7777 and the corresponding Adjacent X.121 Address **1204** of 3745 from the address configuration table entry **1212**, and dynamically allocates an X.25 LCN from among the "virtual pool" of unused X.25 LCNs. For example, assume that the enhanced router device **43** allocates the X.25 LCN 2. The enhanced router device **43** then attempts to connect to the SNA mainframe **42** over the dynamically allocated X.25 LCN 2 using a calling X.121 address equal to the Partner X.121 Address **1406** of 7777 and a called X.121 address equal to the Adjacent X.121 Address **1404** of 3745. If the enhanced router device **43** is able to establish the connection to the host SNA mainframe **42**, then the enhanced router device **43** installs a dynamic

routing table entry in the dynamic routing table mapping the AS/400 **463** to the host SNA mainframe **42**.

FIG. 13 shows an exemplary dynamic routing table **1300** including a dynamic routing table entry **1312** mapping the AS/400 **463** to the host SNA mainframe **42**. The dynamic routing table entry **1312** includes an Adjacent X.121 Address field **1304** equal to the Adjacent X.121 Address of 3745, a Partner X.121 Address field **1306** equal to the Partner X.121 Address of 7777, an X.25 LCN field **1307** equal to the dynamically allocated X.25 LCN of 2, an Adjacent MAC Address field **1308** equal to the Adjacent MAC Address of 400000000004, and a Partner MAC Address field **1310** equal to the source MAC address of 400000000002. The enhanced router device **43** uses the dynamic routing table entry **1312** to translate between X.121 addresses and MAC address for communication between the AS/400 **463** and the host SNA mainframe **42**. For example, when the enhanced router device **43** receives an X.25 packet from the host SNA mainframe **42** including a calling X.121 address of 3745 and a called X.121 address of 7777 over X.25 LCN 2, the enhanced router device **43** uses the dynamic routing table entry **1312** to translate the calling X.121 address of 3745 into a source MAC address of 400000000004 and to translate the called X.121 address of 7777 into a destination MAC address of 400000000002. Similarly, when the enhanced router device **43** receives a DLSw packet from the AS/400 **463** including a source MAC address of 400000000002 and a destination MAC address of 400000000004, the enhanced router device **43** uses the dynamic routing table entry **1312** to obtain the X.25 LCN of 2 and to translate the source MAC address of 400000000002 into a calling X.121 address of 7777 and the destination MAC address of 400000000004 into a called X.121 address of 3745.

DYNAMICALLY ALLOCATE PARTNER X.121 ADDRESS

FIG. 14 shows an exemplary address configuration table **1400** for use in the enhanced router device **43** when the enhanced router device **43** dynamically allocates the Partner X.121 Address. The address configuration table **1400** includes a single address configuration table entry **1412** for mapping the DLSw devices (**461**, **462**, **463**) to the host

SNA mainframe **42**. The address configuration table entry **1412** includes a Map Name field **1402**, an Adjacent X.121 Address field **1404**, a Partner X.121 Address field **1406**, an Adjacent MAC Address field **1408**, a Partner MAC Address field **1410**, and a Flag field **1411**. The Map Name field **1402** includes an address configuration table entry name, which, in this example, is "NPSI_host." The Adjacent X.121 Address field **1404** includes the X.121 address 3745 that is associated with the host SNA mainframe **42**. The Partner X.121 Address field **1406** is blank (nil). The Adjacent MAC Address field **1408** includes the MAC address 400000000004 that is associated with the host SNA mainframe **42**. The Partner MAC Address field **1410** includes a "wildcard" matching all DLSw device addresses. The Flag field **1411** is equal to one, which indicates that there is a "wildcard" in the Partner MAC Address field **1410**.

When, for example, the AS/400 **463** initiates a connection to the SNA mainframe **42**, the AS/400 **463** generates a connection request including, among other things, a source MAC address equal to the MAC address of the AS/400 **463** (400000000002) and a destination MAC address equal to the MAC address of the SNA mainframe **42** (400000000004). When the enhanced router device **43** receives this connection request from the AS/400 **463**, the enhanced router device **43** searches the address configuration table **1400** for an address configuration table entry having a Partner MAC Address **1410** matching the source MAC address of 400000000002 and an Adjacent MAC Address **1408** matching the destination MAC address of 400000000004. In this example, the enhanced router device **43** finds the address configuration table entry **1412**.

Upon finding the table entry **1412**, enhanced router device **43** obtains the corresponding Adjacent X.121 Address **1404** of 3745 from the address configuration table entry **1412**, but is unable to obtain the corresponding Partner X.121 Address from the address configuration table entry **1412** since the Partner X.121 Address **1406** is "nil." Therefore, the enhanced router device **43** allocates the Partner X.121 Address from a pool of X.121 addresses. For example, assume that the enhanced router device **43** allocates the X.121 address 8888 from a pool of X.121 addresses. The enhanced router device **43** then attempts to connect to the SNA mainframe **42** over the predetermined X.25 LCN 1 using a calling X.121 address equal to the dynamically allocated Partner X.121 Address of 8888

and a called X.121 address equal to the Adjacent X.121 Address **1404** of 3745. If the enhanced router device **43** is able to establish the connection to the host SNA mainframe **42**, then the enhanced router device **43** installs a dynamic routing table entry in the dynamic routing table mapping the AS/400 **463** to the host SNA mainframe **42**.

FIG. 15 shows an exemplary dynamic routing table **1500** including a dynamic routing table entry **1512** mapping the AS/400 **463** to the host SNA mainframe **42**. The dynamic routing table entry **1512** includes an Adjacent X.121 Address field **1504** equal to the Adjacent X.121 Address of 3745, a Partner X.121 Address field **1506** equal to the dynamically allocated Partner X.121 Address of 8888, an X.25 LCN field **1507** equal to the predetermined X.25 LCN of 1, an Adjacent MAC Address field **1508** equal to the Adjacent MAC Address of 400000000004, and a Partner MAC Address field **1510** equal to the source MAC address of 400000000002. The enhanced router device **43** uses the dynamic routing table entry **1512** to translate between X.121 addresses and MAC address for communication between the AS/400 **463** and the host SNA mainframe **42**. For example, when the enhanced router device **43** receives an X.25 packet from the host SNA mainframe **42** including a calling X.121 address of 3745 and a called X.121 address of 8888 over X.25 LCN 1, the enhanced router device **43** uses the dynamic routing table entry **1512** to translate the calling X.121 address of 3745 into a source MAC address of 400000000004 and to translate the called X.121 address of 8888 into a destination MAC address of 400000000002. Similarly, when the enhanced router device **43** receives a DLSw packet from the AS/400 **463** including a source MAC address of 400000000002 and a destination MAC address of 400000000004, the enhanced router device **43** uses the dynamic routing table entry **1312** to obtain the X.25 LCN of 1 and to translate the source MAC address of 400000000002 into a calling X.121 address of 8888 and the destination MAC address of 400000000004 into a called X.121 address of 3745.

AN EXEMPLARY NETWORK DEVICE

FIG. 5 is a block diagram showing the relevant logic blocks of an exemplary network device **500**, such as the enhanced router device **23** shown in FIG. 2 or the

enhanced router device **43** shown in FIG. 4. The network device **500** includes, among other things, an X.25 Interface **502**, Switching/Routing Logic **504**, a DLSw Interface **506**, one or more Address Pools **508**, Connection Control Logic **510**, a Dynamic Routing Table **512**, an Address Configuration Table **514**, a Management Information Base (MIB) **516**, and a Management Agent **518**. The Connection Control Logic **510** establishes connections between X.25 devices and DLSw devices. The Connection Control Logic **510** is coupled to the Address Configuration Table **514** and to the Address Pools **508**. The Connection Control Logic **510** utilizes the Address Configuration Table **514** to establish the connections, which may include dynamically allocating an Adjacent MAC Address or a Partner X.121 Address from the Address Pools **508**. Upon establishing a connection, the Connection Control Logic **510** installs a dynamic routing table entry in the Dynamic Routing Table **512**. The Switching/Routing Logic **504** utilizes the Dynamic Routing Table **512** for forwarding packets between the X.25 Interface **502** and the DLSw Interface **506**.

In an exemplary embodiment of the invention, the address mapping information in the Address Configuration Table **514** and the MAC addresses in the MAC address pool **508** are managed through Management Information Bases (MIBs) **516**, which are accessible through the Management Agent **518**. The Management Agent **518** is typically a Simple Network Management Protocol (SNMP) agent, in which case the MIBs **516** are SNMP MIBs. Exemplary SNMP MIBs for managing the Address Configuration Table **514** and for managing the MAC address pool **508** are shown and described in the related patent application entitled MANAGING ADDRESSES IN A COMMUNICATION SYSTEM, which was incorporated by reference above.

Within the network device **500**, regular expressions may be used to configure the Adjacent X.121 Address for X.25-to-DLSw connections or the Partner MAC Address for DLSw-to-X.25 connections. Regular expressions may also be used to configure the MAC address pool or X.121 address pool. For example, the regular expression ".*" may be configured as the Adjacent X.121 Address in order to map all X.25 devices to a single DLSw device, or the regular expression ".*" may be configured as the Partner MAC Address in order to map all DLSw devices to a single X.25 device. A regular expression

such as "40000000000[567]" may be used to configure a MAC address pool including the addresses 400000000005, 400000000006, and 400000000007.

In the exemplary embodiments of the invention described herein, there are certain rules for configuring the addressing information, and in particular for using regular expressions for encoding the Adjacent X.121 Address or the Partner MAC Address. First of all, either the Adjacent X.121 Address field or the Partner MAC Address field may be configured using a regular expression, but not both. A regular expression in the Adjacent X.121 Address field replaces and represents one or more X.121 addresses, where each X.121 address comprises from 1 to 15 decimal digits. A regular expression in the Partner MAC Address field replaces and represents one or more MAC addresses, where each MAC address comprises 12 hexadecimal digits. If the Partner MAC Address field is configured using a regular expression, then the Flag field (MIB management object wfX25QllcAddrMapOptions at the bit position corresponding to the decimal value 4) must be set so that the Connection Control Logic **510** will not mistake the regular expression for an actual MAC address.

ALTERNATIVE EMBODIMENTS

As described herein, regular expressions may be used for configuring and storing address configuration information and also for configuring address pools. However, the present invention is in no way limited to such uses. Regular expressions can be used in many other contexts for configuring and storing addressing information. For example, a regular expression may be used in a routing table to consolidate routing information for addresses belonging to a particular Forwarding Equivalence Class (FEC). A regular expression may also be used to define group membership, for example, for a multicast group or distribution list. These and other applications that utilize a regular expression for configuring and/or storing addressing information are intended to fall within the scope of the invention.

One regular expression syntax is described herein for use in configuring and storing addressing information in a network device. However, the present invention is in

no way limited to any particular regular expression syntax. There are other regular expression syntaxes, such as "Unix" regular expressions and regular expressions described in the book entitled Mastering Regular Expressions written by Jeffrey E. Friedl and published by O'Reilly Publishing (incorporated herein by reference in its entirety), that can be used in whole or in part for use in configuring and storing addressing information in a network device.

Even though the preceding discussion of using regular expressions for configuring and storing addressing information has been in the context of a "router", other types of computer network devices could also benefit, including, but not limited to, switches, gateways, bridges, bridge-routers, etc. One specific embodiment is exemplified in the BayRS version 12.10 router software program sold by Nortel Networks, described in the Nortel Networks technical documentation entitled *Configuring X.25 Services*, Nortel Networks part no. 11737-B Rev. 00, the entirety of which is hereby incorporated herein by reference.

Although various embodiments are described herein with reference to a communication system having an X.25 network that is interconnected with a DLSw network through a router, it should be noted that the present invention is in no way limited to any particular network topology or network protocols.

In an exemplary embodiment of the present invention, predominantly all of the connection control logic and management agent logic described herein is implemented as a set of computer program instructions that are stored in a computer readable medium and executed by an embedded microprocessor system within the network device. Various embodiments of the invention may be implemented in any conventional computer programming language. For example, an embodiment may be implemented in a procedural programming language (*e.g.*, "C") or an object oriented programming language (*e.g.*, "C++"). Alternative embodiments of the invention may be implemented using discrete components, integrated circuitry, programmable logic used in conjunction with a programmable logic device such as a Field Programmable Gate Array (FPGA) or microprocessor, or any other means including any combination thereof.

Alternative embodiments of the invention may be implemented as a computer program product for use with a computer system. Such implementation may include a series of computer instructions fixed either on a tangible medium, such as a computer readable media (*e.g.*, a diskette, CD-ROM, ROM, or fixed disk), or fixed in a computer data signal embodied in a carrier wave that is transmittable to a computer system via a modem or other interface device, such as a communications adapter connected to a network over a medium. The medium may be either a tangible medium (*e.g.*, optical or analog communications lines) or a medium implemented with wireless techniques (*e.g.*, microwave, infrared or other transmission techniques). The series of computer instructions embodies all or part of the functionality previously described herein with respect to the system. Those skilled in the art should appreciate that such computer instructions can be written in a number of programming languages for use with many computer architectures or operating systems. Furthermore, such instructions may be stored in any memory device, such as semiconductor, magnetic, optical or other memory devices, and may be transmitted using any communications technology, such as optical, infrared, microwave, or other transmission technologies. It is expected that such a computer program product may be distributed as a removable medium with accompanying printed or electronic documentation (*e.g.*, shrink wrapped software), preloaded with a computer system (*e.g.*, on system ROM or fixed disk), or distributed from a server or electronic bulletin board over the network (*e.g.*, the Internet or World Wide Web).

The present invention may be embodied in other specific forms without departing from the essence or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive.